# USE OF MOUSE TRACKING TO EVALUATE THE OPERATOR EFFICIENCY ON TRAIN DISPATCHER WORKSTATIONS

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**ABSTRACT**
The operator efficiency describes the ability of an operator to bundle operational actions in terms of space and time in order to achieve an efficient, i. e. time saving operational process with a close correlation with the situational awareness. The operator efficiency depends as well on the design of the user interface as on the training level of the operator. Mouse tracking is a proven method applied in usability engineering to study operator behaviour. Two case studies based on train dispatcher workstation simulations in a railroad operations laboratory have been investigating whether mouse tracking analyses allow to prove the influence of the training level of different operators as well as the influence of changed operational functions on the operator efficiency.

## RESEARCH QUESTION

Over the last decades, the development of train dispatching technologies has resulted in a highly centralized control of train operations. While the basic principles of railroad operations are still the same, the workplace of a train dispatcher has changed significantly.

To meet the requirements of modern railroad operations, the design of the man machine interface (MMI) must keep track with the development of the control technology. For this, the operator becomes a subject of research. One aspect of that research is situation awareness. Situation awareness describes the ability of the operator to establish a complete understanding of all elements describing the situation in its current state and its future development *(1).*

The situation awareness is rather a perception phenomenon relevant for correct decision making. After a decision has been made, the operator has to perform adequate action on the MMI. The quality of the operator's actions to realise a decision on the user interface (UI) is described by the so-called operator efficiency. The term is quite new and still in the process of being commonly accepted. Situation awareness and operator efficiency form a closed loop describing the interaction between operator and UI (FIGURE 1).

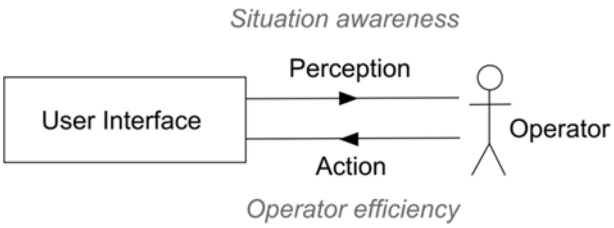


**FIGURE 1 Situation awareness and operator efficiency.**

## EVALUATION OF OPERATOR EFFICIENCY

The term operator efficiency is currently more and more frequently used, in particular in publications of manufacturers of industrial control systems *(2)*. However, since it is still a quite new point of view, a commonly accepted definition has not yet been established. Also, there are not yet generally accepted measures and methods for the evaluation of the operator efficiency. In publications dealing with operator efficiency in production systems, a throughput-oriented approach is common, either by measuring the frequency of operator action on a per-time basis, or by comparing the time used to perform a specific operation with the theoretically minimum in which this operation could be performed *(3, 4)*.

In traffic control systems, this would not be an appropriate approach. While the process with its traffic flow and structure is determined from outside, the operator has no influence on the throughput but on the quality of service. For that reason, a more generic definition of operator efficiency is proposed:

*The operator efficiency describes the ability of the operator to perform operating actions in a time- and space-efficient way.*

The operator efficiency depends on two key factors:

- The user interface design (generally known as UI efficiency)
- The qualification and training level of the operator

The design of user-friendly interfaces is the key subject of usability engineering. In the last years, one of the big research issues in this field was the design of user-friendly interfaces for intuitional operation, e.g., on ticket machines and web interfaces *(5)*. Qualification and training level of the operator connects the operator efficiency with situation awareness. An operator with a high degree of situation awareness will be able to plan operating actions in a more efficient way by anticipating the development of the operational situation *(6)*.

By varying one of these two factors without changing the other one, the particular influence of this factor on the operator efficiency can be investigated. For example, to investigate the influence of the user interface design on operator efficiency, the operator efficiency of differently designed interfaces may be compared using the same process and the same operator. If, instead of the interface design, procedures for emergency situations or degraded mode operations are varied, knowledge on the efficient design of operating rules may be derived. A useful application for the evaluation of the operator efficiency of different operators using the same user interface and the same process would be to measure the training success when operators are trained for a new territory.

**RESEARCH METHODOLOGY**

Selecting a suitable method for evaluation of operator efficiency is quite a challenge since human behaviour is way too complex to be described by just a single measure. This problem is not new and has always been a challenge for the development of user interfaces. Single parameters like the number of menu levels or the average number of mouse clicks will hardly provide suitable measures for the UI efficiency. To solve this problem, user interface developers have recently started to use spatial analysis. Spatial analysis is a rather general term for techniques describing entities based on topological, geographical, or geometrical properties. For the development of computer-based user interfaces, a typical approach is to visualise user action by trajectories *(7)*.

For evaluation of the operator efficiency, the same principle is used here by tracking the operator's action and displaying it in a graphical way. On a mouse-controlled user interface, mouse tracking is a very useful tool for this purpose. Mouse tracking is already a widely accepted method in usability engineering with a lot of tools available *(8)*. The main application is the evaluation of web interfaces *(9, 10)*. A rather new development is eye-tracking. There are ongoing discussions among usability experts on the pros and cons of mouse tracking versus eye tracking. Some authors state a strong correlation between the results of mouse tracking and eye tracking analysis *(11)*, while other authors question the approach to gain these results and deny that strong correlation *(12)*. There is even the statement that mouse tracking will generally produce more valuable results than eye tracking *(13)*.

It seems that the correlation depends on the kind of task the user has to perform. The closer the action items the user has to click on to perform a desired operation are related with the display elements the user has to read for decision making, the stronger is the correlation between mouse and eye movement. On a train control screen, this correlation is expected to be rather low. To understand the current operational situation, the operator has to read a lot of information from different parts of the control screens. The action items to perform an operation may be concentrated at specific locations on the UI, however. There may be windows with important information that do not contain any clickable elements. Since the objective of this study was to evaluate the operator efficiency, which is closely related with the operator's action, mouse tracking was considered a more suitable approach to get reasonable results. As another advantage, mouse tracking can be performed in the background without being noticed by the operator. It can even be done without telling the operator about the recording. There is no need to wear any specific garments that would change the working conditions. This avoids the 'observer effect' (also known as the 'Hawthorne Effect') that is caused by the fact that a person who knows that every move is being monitored, cannot be expected to act naturally *(11)*.

These advantages of mouse tracking are only relevant on user interfaces where the operator's action is performed by mouse operations. While this is true for train control workstations where the dispatcher authorizes movements by lining up routes and clearing signals, the situation in air traffic control is completely different. On an air traffic control workstation, the operator controls traffic not my mouse operations on the control screen but by verbal communication with the aircraft crews. That's why, in air traffic control, only eye tracking will provide reasonable results.

In usability engineering, the typical approach is to use mouse tracking for comparative analysis. However, not every mouse tracking solution is useful for evaluation of the operator efficiency. Many mouse trackers track mouse clicks and deliver click heat maps of many kinds. That is the traditional method to analyze user behaviour on web sites. However, recent research brought up the result that the value of click recording is quite limited. Even for web site analysis, tracking of mouse movements is more appropriate for evaluation of user behaviour *(14)*.

On a dispatcher's control interface, the number of mouse clicks on individual elements directly depends on the number of train moves on different routes. Thus, a click heat map would not provide any useful information. If the mouse tracker does not only record mouse clicks but also the mouse trajectory, it's already possible to get a picture on the space efficiency of the operator's action. For specific psychological studies, in particular on decision making, recorded mouse trajectories are considered a valuable tool *(15)*. For the evaluation of the operator efficiency, it's also valuable, but not yet sufficient. To evaluate the time efficiency of the operator's action, instead of mouse clicks, a record of the mouse dwells within the trajectory is needed. By this, the mouse trajectory describes the space efficiency, and the mouse dwells the time efficiency of the operator's action. This quite exactly meets the characteristics of the definition suggested for operator efficiency earlier in the paper.

For the case studies described in the following chapters, a mouse tracker was used that records the mouse trace and visualizes each dwell point by two concentric circles. For the inner circle, which is filled by color, the area represents the dwell time. For the outer circle, the dwell time is represented by the diameter (FIGURE 2). The outer circle grows much faster and leaves the screen after just a few minutes. That circle is only relevant for the investigation of systems with very short intervals between operator's actions. While, for railroad traffic control, that circle doesn't produce a valuable visualization, the slow growing inner circle fits perfectly.

Such a mouse tracker was used for recording operating sessions in the Virtual Railroad Operations Laboratory at TU Braunschweig *(16)*. That laboratory is a simulation environment consisting of a number of train dispatcher workstations arranged in separate cubicles and connected to a virtual railroad network, in which rail traffic is simulated. There are a number of different networks that can be simulated, among them German and foreign standard railroads but also rail transit systems. Most simulation networks require up to five operators to control the traffic. Some networks are copies of real places including the original control screen displays, others are fictitious territories designed for research and training purposes without following a specific prototype. Two of these networks were used in the case studies described below. While the mouse tracker used in the laboratory experiments meets the requirements stated in the previous paragraph, it still had the shortcoming of not producing any statistical data but only graphical recordings. However, to get first results on the usefulness of mouse tracking on train control interfaces, this was acceptable.

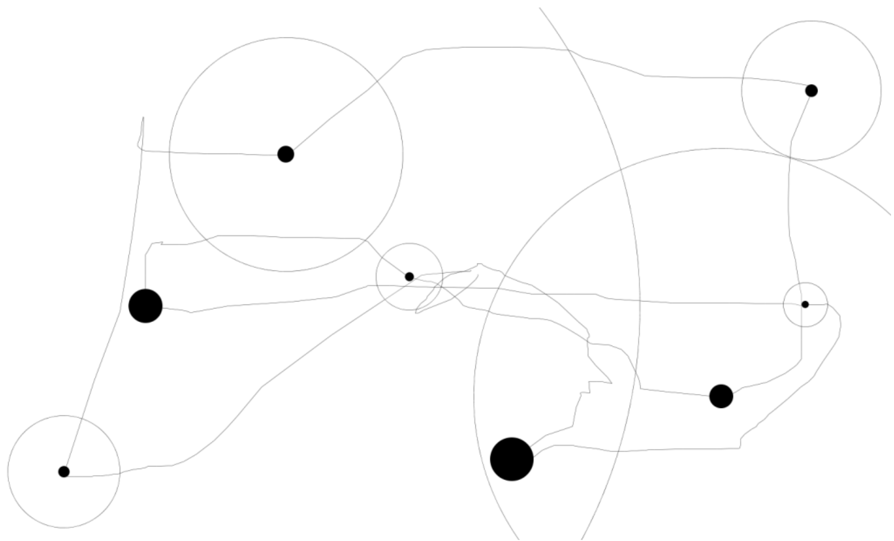

**FIGURE 2 Principle of mouse tracking by recording traces and dwell points.**

## EVALUATION OF THE SKILL LEVEL OF A TRAIN DISPATCHER WHEN BEING TRAINED FOR A NEW TERRITORY

The objective of the first case study was to test the use of mouse tracking as a tool to evaluate the skill level of a train dispatcher when taking over a new territory. For this research, the control panel of a fictitious German station area was simulated. The control interface represents a traditional push button panel still widely used in relay-based German CTC systems. A simulation of such a relay panel is also a standard tool used by German Railways (Deutsche Bahn) for the basic training of new train dispatchers. Different from that training tool, which is a stand-alone simulation of a small territory, the control area 'Rebenau' used here is part of a larger network that is used for students training sessions on a regular basis. The Rebenau control district consists of a station area with five main tracks located on a double-track line with a diverging single-track line. The operating session in this case study covered the morning peak hour from 6:00 am to 8:30 am. During this period, the operator has to handle 48 trains and 5 switching moves. Most of the traffic is passenger, so punctuality plays an important role. For each operator, the traffic simulation started with exactly the same initial situation. During the session, the situation may develop differently depending on the experience of the operator, however.

The statement to be approved in this experiment was that a well-trained operator would use the mouse in more purposeful way than an operator with a lack of training for that specific territory. The higher operator efficiency will not only be shown in less mouse traces but also in a lower number of dwell points but with greater dwell times.

Prior to the experiment, the candidates were trained using the DB standard training simulation mentioned above. So, all candidates had quite the same skill level in operating this type of control system. For the experiment, two candidates were selected. One candidate was a teaching person that developed the laboratory timetable. By being familiar with all details of the infrastructure, that candidate had a level situation of awareness that could hardly be further improved. The second candidate hadn't operated that territory before but was given an introduction to the infrastructure and the characteristics of timetable. This way, that candidate represented an operator who has just started to become familiar with that territory.

FIGURE 3 shows the Rebenau control panel, in which a characteristic area is marked that will be used to demonstrate the mouse tracking results. While the mouse tracking was recorded for the entire control area, this cutout provides a more convenient diagram for use in illustrations and presentations. FIGURE 4 shows the mouse tracking record for the marked area. Actually, comparing the mouse tracking record of any other part of the area would provide quite the same results.

The results supporting the statement to be approved by this experiment are even more convincing than expected. The untrained operator did not only produce much more mouse traces but also a much greater number of small mouse dwell points. So, it might be worth to conduct further tests to show how the graduate improvement of the skills during the training period can be represented by mouse tracking records.

Additional tests of the same type with other unexperienced operators brought the result that, for individual operators, mouse tracking records may quite differ in the location of dwell points and the pattern of the mouse traces. However, for different operators of the same skill level, the average number and size of the dwell points, and the density of mouse traces look very alike. It was always possible to clearly identify unexperienced operators just by the mouse tracking record. More tests to support this experience will follow.

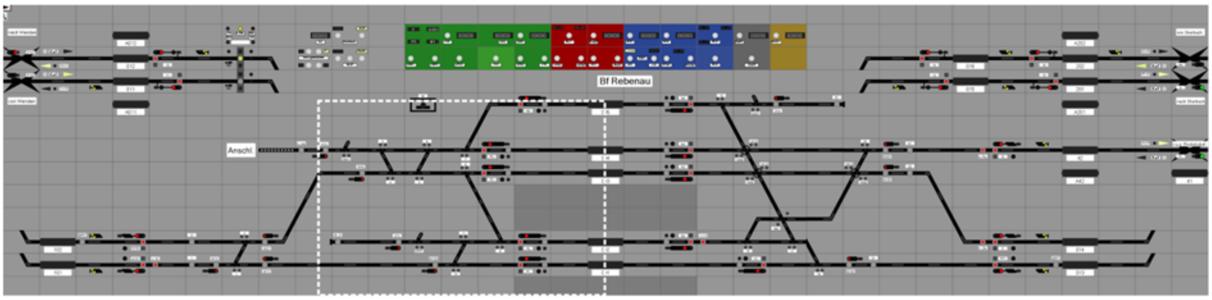


**FIGURE 3 Rebenau control panel with a marked area.**

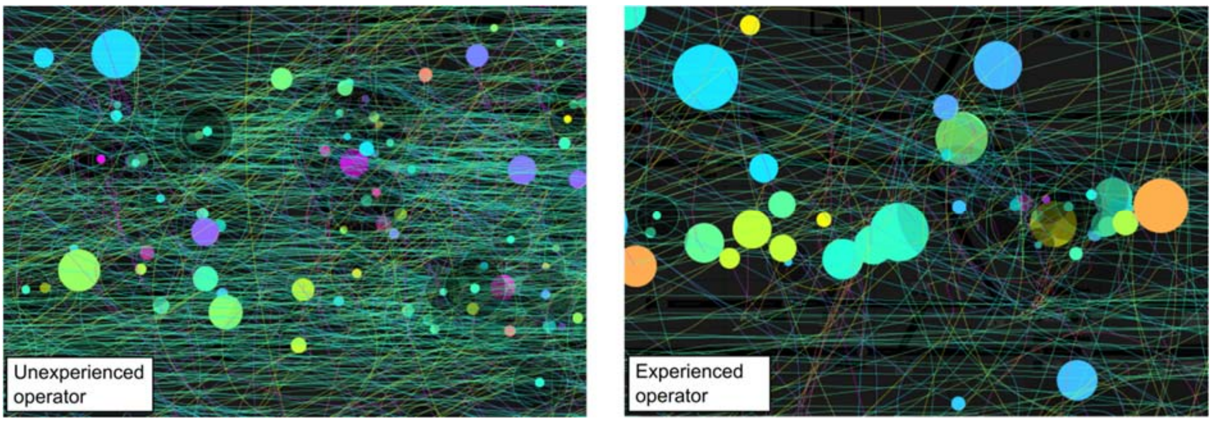

**FIGURE 4 Mouse tracking records for the marked area of the Rebenau panel.**

## EVALUATION OF THE INFLUENCE OF UI FUNCTIONS

For the second use case, another experiment was done in the Virtual Railroad Operations Laboratory. For this experiment, a simulation of the train control system of the Wembley Suburban Line in the North-West of London, UK, was used. That line is controlled by Network Rail's standard control system IECC (Integrated Electronic Control Centre). For this simulation, which was developed for dispatcher training, TU Braunschweig was granted the right to use it for research projects on a non-profit basis. The line leads from Euston station (outside the control territory) to Watford Junction. While the infrastructure is owned by British infrastructure manager Network Rail that is also in charge for train control, the line is also used by London Underground trains of the Bakerloo line between stations Queens Park and Harrow & Wealdstone. As typical for rail transit operations, the track layout is rather simple. Due to the high density of traffic and the lack of automatic route setting (only simple fleeting mode at selected signals), train control requires some concentration, however.

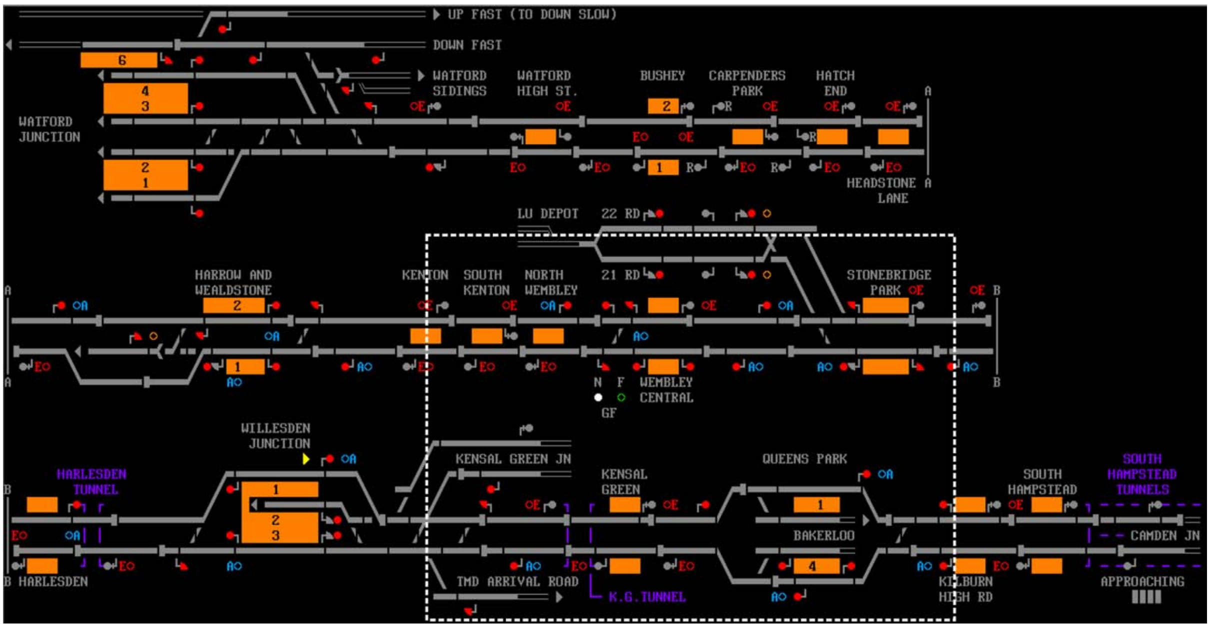


**FIGURE 5 Wembley control screen with a marked area.**

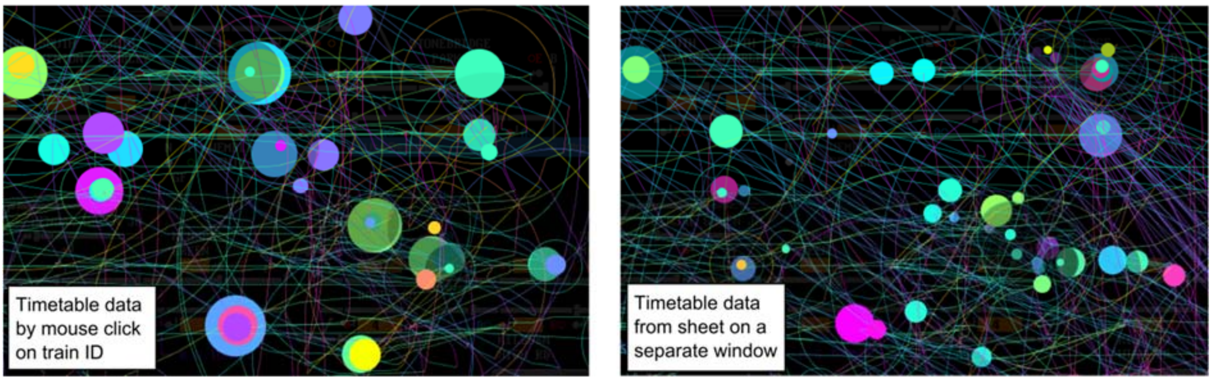


**FIGURE 6 Mouse tracking records for the marked area of the Wembley screen.**

With this simulation, two simulation runs of one hour were conducted. In both runs, the simulated period was from 0500 to 0600 in the morning. That hour is directly followed by the morning peak. A lot of switching moves and empty train runs require a lot of operator's action on the UI. The same operator controlled both simulation runs using the same timetable. The only difference was to switch off a specific function of the UI. Normally, the operator will get timetable and train routing data of individual train on a mouse click on the train ID in the track chart display. In the second simulation run, this function was disabled. Instead, the operator had to get that information from a tabular sheet presented in a screen window separated from the track chart display. Since the training effect of running the same simulation twice may influence the results, the operator did several training runs prior to the test to make sure just one run more will not significantly improve the performance.

FIGURE 5 shows the track chart display on the control screen. Again, an area is marked to be used as a cutout for comparing the mouse-tracking results. The mouse tracking records are shown in FIGURE 6. While the difference is not as prominent as in the first use case, the effect is clearly to be seen. However, it was just a small modification of the UI functionality. Without disabling the named function, the average mouse dwell times are greater. That indicates a higher operator efficiency.

## CONCLUSION

The use cases described here are just first experiments. The results are not yet supported by a sufficient number of tests required for statistical relevance. However, they already provide a positive answer to the question whether or not mouse-tracking analysis may support evaluation of operator efficiency. For this, the results are even quite convincing.

Based on these use cases, more research will follow to investigate the possibilities and limitations of this approach. Examples for interesting research questions to work on are the influence of the use of colors on control screens and the impact of changed operating rules for handling of signal failures and for degraded-mode operations on the operator efficiency

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